The Influence of Health on Labor Productivity: An Analysis of European Conscription Data

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Abstract:

Height has been used in a growing literature as a measure of net nutrition throughout the first 20 years of life. This paper builds on that literature by considering the influence that net nutrition has on a population's labor productivity. Using data from Danish and Italian conscription programs, we are able to create a more rigorous estimate of changes in final adult height over a period of 150 years by distributing the measured adult height over the age distribution of the male population. This calculation creates a measure of the age-distributed height of the labor force, which then permits an analysis over a longer period of time than other contemporary essays on height and labor productivity. My findings suggest that net nutrition in people's first 20 years has had a significant and positive effect on labor productivity over the twentieth century. Additionally, I explore and hypothesize on the causal relationship between nutrition and educational achievement.

The Influence of Health on Labor Productivity: An Analysis of European Conscription Data[1]

> *"Nutrition is an input to and foundation for health and development. Interaction of infection and malnutrition is well-documented. Better nutrition means stronger immune systems, less illness and better health. Healthy children learn better. Healthy people are stronger, are more productive and more able to create opportunities to gradually break the cycles of both poverty and hunger in a sustainable way. Better nutrition is a prime entry point to ending poverty and a milestone to achieving better quality of life."*
>
> - World Heath Organization (WHO)

The argument made above is a common opinion held by many, and implicit in it is a belief that somehow nutritional changes in a micro-level setting, say with a single person, can have ramifications for an entire economy. In this paper, I consider the degree to which nutrition matters. It could be argued that nutrition's influence does not extend beyond a single person to cause changes in the entire economy. Social scientists have for years explored the effects of increased wages on nutrition, disease, technology, and migration, and even more recently have began to consider the influence of these elements on labor productivity. This article confronts the latter issue: what are the determinants of labor productivity? I conclude that nutrition, and none of the others, has the most persistent influence on economies when judged from country to country over an extended time period. Therefore, I propose that net nutrition (as measured by final adult height) has a significant influence on labor productivity.

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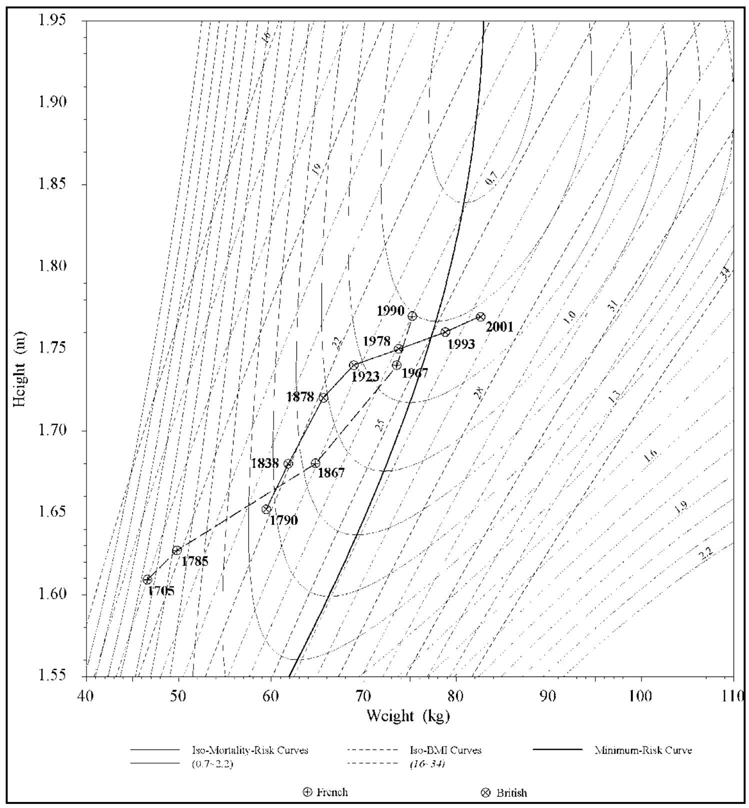
The paper will proceed as follows: Section I will consider the literature on height and net nutrition's influence on labor productivity. Section II will explore the economic histories and challenges faced by the two countries studied in detail here, Italy and Denmark. Section III will develop the theory surrounding the hypotheses. Section IV will elaborate on the sources of data collection and methodological reasoning. Finally, Section V will present the models and the results and Section VI will conclude with a summary of findings and suggestions for future research.

Figure 1



Source: Fogel (2004)

I. *Height and History* [2]

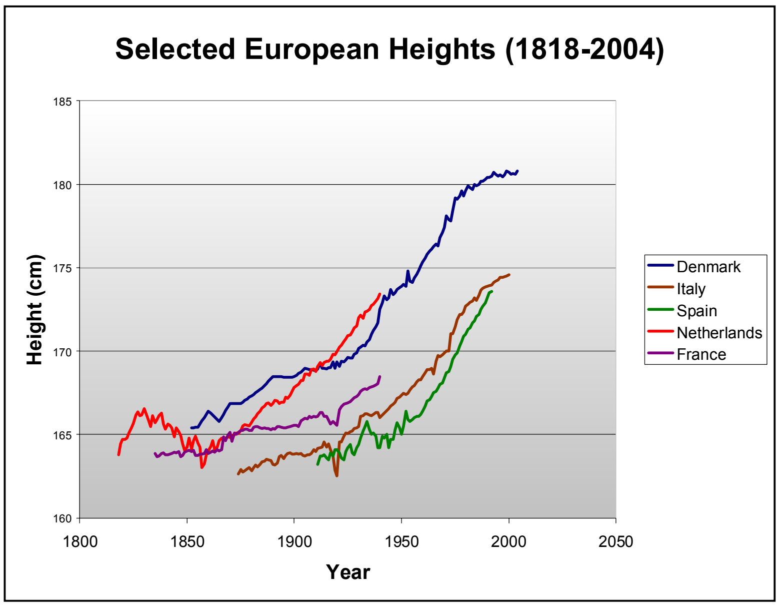
Since 1960, a growing number of anthropologists and economic historians have been collecting height samples going back to the 1700s. Beginning with anthropologists in France, most notably M.C. Chamla, vast amounts of data have been collected from varying military and civilian authorities throughout Western Europe. The data has resurfaced and is being used as a common source to evaluate newly found economic theories regarding stature and its influence on the standard of living. A large portion of the work in this field stemmed from Robert Fogel's use of the Waaler curve to extend the understanding of height and weight's impact on morbidity and

[2] This section draws heavily on an earlier work of Knapp's, written for Trevon Logan's Economic History of Western Europe Class, 8 March 2007.

mortality in later life. The Waaler surface shows that there appears to be more optimal positions for height and weight that can limit mortality risk. Figure 1 is the Waaler Curve used by Fogel in his most recent publication. This graph shows the impact of changes in height and weight of the French and English on the length of their lives (in this case he used Norwegian mortality rates, presumably based on availability of data).

During the end of the nineteenth century and throughout the twentieth, there is an upsurge in European height. This information is highly correlated with other information that we have on well-being such as mortality rate and real per capita income. Figure 2 combines data collected by Drukker and Tassenaar with older work by A. Constanzo. This graph is an illustration of the changes in height experienced in the Western European economies from 1818-2004 (Drukker and Tassenaar 348).

Figure 2



Sources: Drukker, J.W. and Vincent Tassenaar (1997), ISTAT (various years), Denmark Statistik (various years), and A. Costanzo (1947)

Many historical studies that use height as a determinant utilize conscription data. Universal male conscription was popular until recently in many European nations and these programs would often require every male to be weighed and measured. These records have been kept by the respective government or provincial authorities and now offer a means of exploring population height distributions.

Steckel (1983) explores the relationship between productivity and height in which he concludes that per capita income and adult height are determined jointly while causation in per capita income and children's height runs one way (4). From the subsequent tests he runs, Steckel is able to determine that a boy, age 12, with a parents' per capita income of $150 (1970 Dollars) will grow from 137.1 cm to be approximately 160.9 cm. Meanwhile his $5000 per capita counterpart will grow from 149.5cm to reach a final adult height of 173.1cm (4). From this information, a clear disparity emerges between people of differing economic backgrounds.

Using OLS regressions on national surveys in Brazil, Ghana and the U.S. from 1987-93, Schultz (2002) is able to analyze the wage gain associated with increased height. He determines that a one centimeter height change is associated with an 8-10 percent increase in wages. However, he notes that the "apparent 'return' on health human capital cannot yet be attributed to a particular intervention for which the costs can be calculated and measured against height" (Schultz 352). In addition, Strauss and Thomas' (1998) survey of the literature on the subject of height and nutrition finds that a small number of studies suggest that nutrition has a greater return in situations where the laborers are in poorer health. Furthermore, Strauss and Thomas posit that, with greater economic growth, the labor market effects of improved nutrition may decline (813). These core concepts, summarized by Strauss and Thomas, serve as the foundation for analyzing the historical impact of height change on labor productivity.

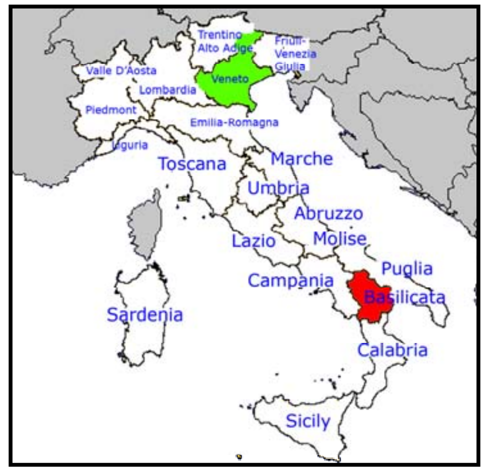
The next section will now place the changes of height and productivity in the historical contexts of the two countries this paper considers: Italy and Denmark.

II. *European Economic Histories*

Italy

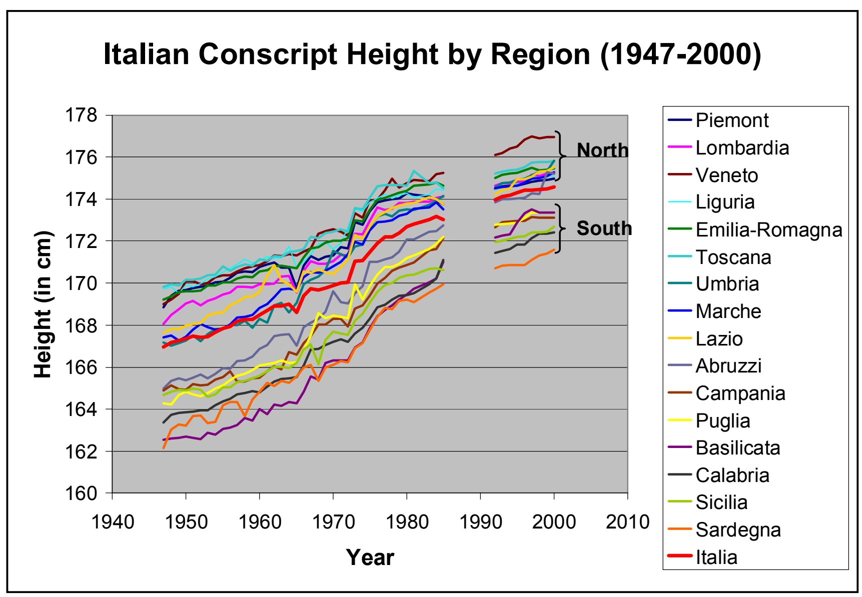
Prior to unification, what is now modern day Italy underwent a series of invasions and occupations by foreign nations that permitted varying levels of economic and social freedoms. When Italy was unified in 1861, levels of prosperity varied substantially between regions, but this difference was most apparent in what is now characterized as the north-south divide. The northwestern part of Italy, or the industrial triangle of Milan, Genoa, and Turin, was the major source of economic growth in the early years of unified Italy. As would be expected, this divide led to substantial variation in living conditions, where the south reflected conditions in the poorer Mediterranean countries and the north reflected conditions in the more affluent European countries. This regional divergence was reflected in adult height, which, in 1894 for example, varied between 159.3cm in the southern province of Basilicata and 166.7 cm in Veneto (where Venice is located).

Figure 3



Modern Italy and its regions

Figure 4



Source: ISTAT (various years), and A. Costanzo (1947)

However, over the course of the 20th century, there has been a tremendous convergence in height. The same provinces which had differed in height by 5.83 cm in 1894, now in 2000 only varied by 1.74 cm, a change of 4.09 cm. More striking than this anecdote is what it suggests for Italy over the past century, which is that it has been transformed from an economy that lagged behind its counterparts in Europe to an economy that now matches (and in some cases exceeds) the economies of Northern Europe.[3]

The leaders of the new unified Italy in 1861 embarked on a number of policies aimed at bolstering the Italian economy, including universal primary education, introduction of an income tax, balanced budget, adoption of the gold standard, and free trade.[4] However, these policy adjustments did not spur the Italian economy forward in any markedly different way during the first years of the new country. Major industries would eventually develop in varying parts of Italy through the latter quarter of the nineteenth century, but they were also matched by fervent protectionist policies beginning in 1887 (Zamagni 2003, 182). In 1894, Italy left the gold standard, and began a period of economic growth that continued at a yearly rate of 7-8 percent before slowing prior to World War I. Following the war, Italy experienced a series of economic challenges. While the economy in America was booming, Italy experienced a period of inflation, disease, bankruptcy, and trade union unrest (Zamagni 2003, 182). This led to the rise of Benito Mussolini and an authoritarian government which persisted until 1943. Mussolini's rule did not halt industrialization; however, its performance was poor compared to that of the Italian economy at the beginning of the century.

Following the end of World War II, Italy rebounded quickly. By 1952, Italy had achieved production levels that were 40 percent higher than in 1938. Furthermore, Italy began a period of rapid growth in the period 1950-70. During this time, the proportion of the national product

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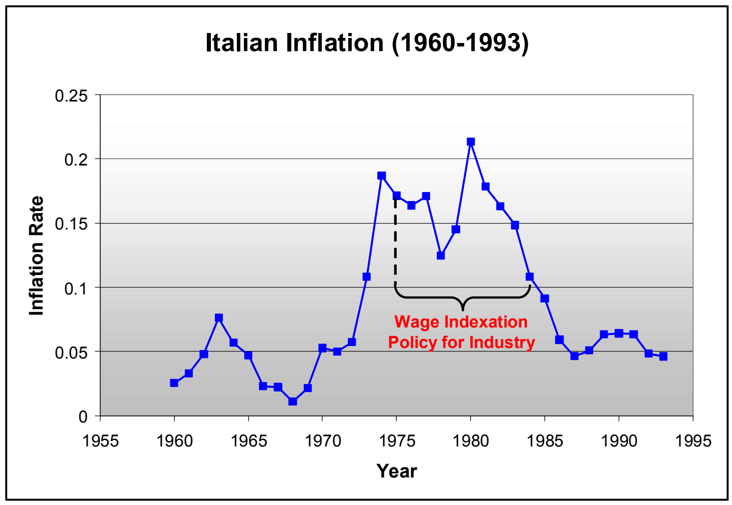
[3] Italy was the 7th richest country in the world in 2006. In income per capita, it occupies 20th, exceeding France and the European Union average (International Monetary Fund)

[4] These policies were achieved over a period of about 16 years, with the initial move towards universal primary education coming in 1859.

coming from agriculture dropped from over 40 percent to below 20 percent. In addition a large portion of the population began to immigrate to other countries in Europe such as the United Kingdom, Germany, and Belgium (Cavotora 229). Emigration from 1951-70 was 5.6 million, of which 62.3% were from the poorer south (Zamagni 1993, 370)

However, the late 1970s saw a large shift in government policy towards increasing social programs (the creation of the National Health Service in 1978, for example). Further, accumulated debt on social security funds had to be repaid and an oil shock caused significant devaluation which forced the suspension of official quotation of the lira (Ferrera and Gualmini 31). Additionally, in 1975, an agreement between business and labor interests led to wage indexing and, hence, inflation, that persisted until 1984 when the political dynamics shifted towards reducing the wage policy (Zamagni 388). Huge public financial debts continued into the 1980s but the situation improved in the 1990s, resulting in an overall rebound.

Figure 5



Source: Mitchell (2003)

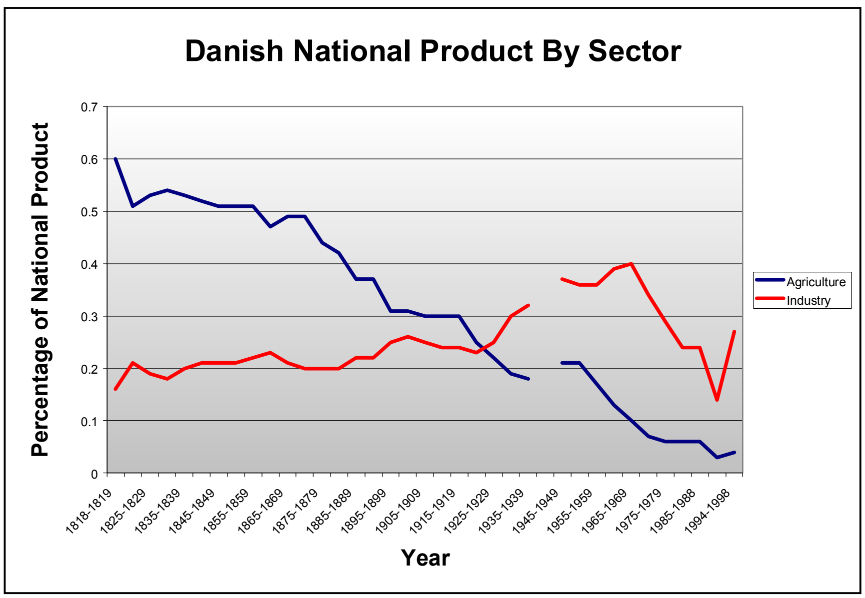
A better understanding of Italy's history helps inform us about the possible elements that could affect this study's evaluation of nutrition's impact on labor productivity. First of all, the aforementioned data indicates that migration could have had an effect on labor productivity. Additionally, the implementation of social welfare policy may alter real wages adding additional incentives or disincentives to working harder and being more productive. In particular, the years from 1975-84 experienced artificial increases in the real wage followed by a period of wage readjustment.

After investigating the history of Italy from unification to the present, there is a better understanding of the major changes which may distinguish Italy from the other European countries that could be tested (in this case, Denmark). Italy's history indicates that rapid industrialization throughout the twentieth century has resulted in convergence across the country, but it has also paralleled large migratory flows. Therefore, these characteristics are critical to consider when selecting exogenous variables for testing the hypotheses.

Denmark

Similar to Italy, Denmark's economy was primarily agricultural at the beginning of the twentieth century. However, the percentage of the labor force in agriculture was eventually surpassed by the industrial sector in the late 1920s. The industrial sector produced mainly for the domestic market with the exception of a few major industries including cement and shipbuilding. The industrial rise which began in the 1920s, reached its maximum by the late 1960s when 40 percent of Denmark's national product came from the industrial sector. Conversely, agriculture declined from

Figure 6



Source: Mitchell (2003)

25 percent of the national product in 1920 to 7 percent in 1970 as represented in Figure 6.

Following World War I, Danish leaders made a series of mistakes, by placing more of the country's emphasis on agriculture. Agriculture already made up a substantial portion of Denmark's exports, and when the global depression hit Denmark at the beginning of the 1930s, demand for agricultural exports plummeted resulting in a large drop in Denmark's net exports.[5] Further decline of Danish agriculture could be attributed to European protectionist movements in the 1930s and the 1960s when the major industrial powers erected discriminatory trade barriers, via the Common Agricultural Policy of the European Common Market (Johansen 2003, 101). In 1950, 63% of Denmark's net exports were in agriculture and, as an unfavorable climate for agricultural trade emerged, Denmark would experience below average growth (as compared to its European counterparts) from 1950-57 (Henrikson). This was followed by a period of growth from 1958-72 in which Denmark transitioned into a highly industrialized economy assisted by deliberate industrialization policies to bolster the strength of internationally competitive firms (Johansen 2003, 101). The Danish growth during this time period was also augmented by an economic growth period for most of Northern Europe

Denmark's changes mirror many of those changes that occurred throughout Europe in the twentieth century. Prior to World War I, many Danish people began to migrate to the United States, whereas in more modern times, Denmark, like Italy, is experiencing immigration from Southeastern Europe and non-European countries.

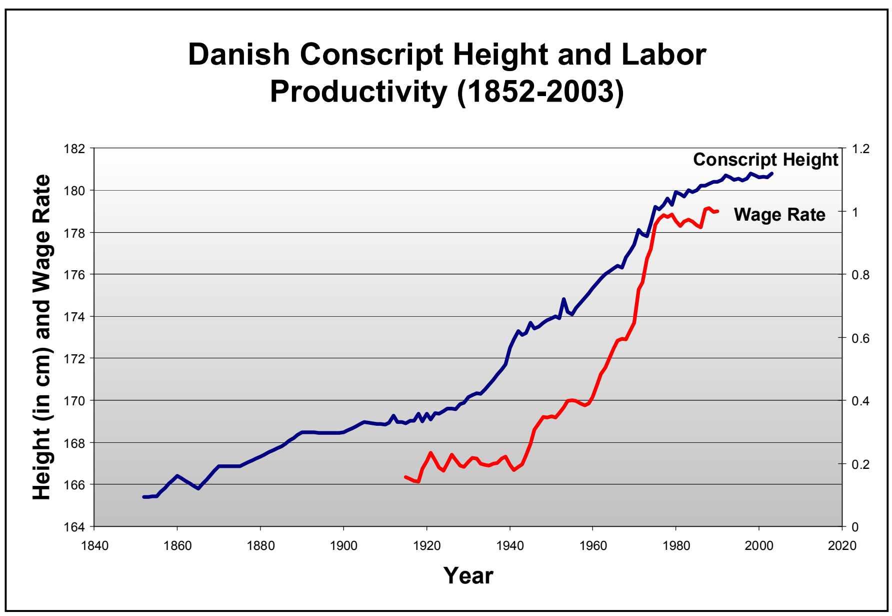
Conscript height stagnated in Denmark beginning in 1890 and grew very little over the next 35 years. In the period 1934-1942 height increased over 2.8 cm and then jumped again, this time by nearly 4 cm between 1955 and 1971. A couple of years of height decline in 1972 and 1973 was followed by another spike in height between 1974 and 1975 of 1 cm. Subsequently,

[5] It was a drop of approximately 24% between 1930 and 1932 (Henrikson).

height has continued to increase, but at much lower rates of growth. Fertility declined in Denmark throughout the 1900s from 30 per thousand in 1900, to 20 per thousand in the 1930s, and to a minimum of less than 10 per thousand in 1983 (Johansen 2003, 100). The only major interruption in this process was a baby boom in the 1940s. Meanwhile, the mortality rate declined in the first half of the twentieth century, but began to trend upwards around the 1950s, which has continued until modern day. A large portion of the mortality rate change can be attributed to an aging population which, as the elderly became a larger portion of the population, naturally caused the mortality rate to increase.

In the 1890s (earlier than many countries in continental Europe), Denmark began different forms of social insurance and support including old-age pensions (1891) and state subsidized health insurance societies (1892). This was shortly followed by unemployment benefits (1907) and disability benefits (1922). However, it was in 1958 that social expenditures began to increase substantially with the creation of a social security system, resulting in increased tax rates. By the end of the century, public services comprised nearly 25 percent of the labor force.

Figure 7



Source: Mitchell (2003), Denmark Statistik (various years).

Labor productivity, as measured by wages in agriculture and industry (distributed based on each sector's proportion of national product), has changed dramatically over the time period discussed here. Figure 7 shows that Danish labor productivity has undergone periods of stagnation and growth similar to the trends in conscript height, albeit with height change occurring a few years prior to productivity changes.[6]

Denmark's economic history informs us of several key factors that may contribute to labor productivity over time. Similar to Italy, major movements of migration prior to World War I could have had a reasonable influence in driving up the wages of those employed in the population. Additionally, changes in mortality are skewed based on age distribution of the population. Linked with this increase in the elderly as a percentage of the population are the possible effects of Denmark's social policy. Since much of its funding was devoted to social policy from the 1960s forward, Denmark's per capita tax burden on the labor force increased markedly over this time period.[7] Theoretically, a heavy tax burden should be expected to diminish the incentive to work, thereby causing wages to decline. Empirical collection limitations will prevent the test of this characteristic.

III. *Theoretical Development*

The objective of this paper is to evaluate the impact of net nutrition on labor productivity, as measured by height and the wage rate (Model 1) or GDP per worker hour (Model 2), respectively.

[6] This refers to the increase in height from 1933-42 which theoretically directed a substantial increase in productivity from 1941-1948, or between 6-8 years later. Additionally the increase in height from 1955-75 was followed by an increase in productivity from 1958-77 or between 2-3 years later. With the increase in social expenditures and incentives to retire from the labor force, it would be understandable that the height effects would influence wage rates sooner in the later period. This can be likened to healthier and more productive twenty year olds engaging more actively in the labor force between 2-8 years later, thereby increasing the wage rate.

[7] And it did, Denmark has one of the highest per capita social expenditures in the world at $29,000 per person (Organisation for Economic Co-operation and Development (OECD). "Welfare Expenditure Report" (Microsoft Excel Workbook), OECD, 2001.)

Hypothesis 1: Net nutrition during the first 20 years of life is a key determinant of labor productivity.

This section explores the theory behind the determinants used in the Labor Productivity models in Section VI. Section V (Data and Sources) elaborates on the sources and limitations of the data used for the concepts presented in this section.

1. Factors generated by net nutrition that effect labor productivity

(Endogenous Factors of Heights)

When Waaler originally conceived his relationship between height, weight, and life expectancy, the role of each component was unknown. It now seems reasonable to assume that height is the measure of nutrition during your first twenty years of life and weight is more reflective of nutritional decisions in the recent term.[8] The unavailability of historical data on weight prevents us from investigating a person's nutritional decisions in later years of life. However, I argue that this is not the most influential effect on a person's productivity. What matters in this argument is that an increase in net nutrition, on average, 1) determines the demand for human capital which occurs for the majority of the population in their early lives (consider learning to read, farm, or more skilled activities), and, more generally 2) improves a person's overall vitality and cognitive ability.

Presumably, an increase in a person's net nutrition during their formative years permits them the opportunity to contribute their time to activities which would develop their human capital. A healthier person is able to attend school regularly (in Italy and Denmark, efforts were made in the 1800s to have universal elementary education and in the 1900s to have universal

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[8] Weight readily fluctuates based upon short term decisions; whereas height is generally stable after the adolescent-growth stage is completed. Additionally, "the underlying causes of adult weight change are not well understood and are the focus of the review papers" (Robert and Williamson, http://jn.nutrition.org/cgi/content/full/132/12/3824S).

secondary education) and work for longer periods of time more efficiently. Moreover, a better nutritional background can help prevent chronic disease and limit the effects of infectious disease.[9] Even more recently, nutrition has been linked to ailments, such as depression, that might otherwise reduce an individual's productivity.[10]

Therefore, height is the best proxy because it is a measure of a person's net nutrition throughout the period when most of their ***development of human capital*** takes place. A shortcoming of this argument is that, as educational attainment begins to stretch beyond the time from which final height is achieved, height becomes a weaker predictor. In both Italy and Denmark, the average years of schooling has not exceeded 12 but growing portions of the labor force have received a college education, meaning that the effect of their nutritional status as measured by height might not be complete.[11] For the purposes of this study, we will recognize this challenge and the possibility that height in more recent history may not be as strong a predictor due to the period of human capital development extending beyond the first 20 years of life (or the period when final adult height is determined). Otherwise, nutrition achieved in childhood and adolescence will relate to a person's educational (human capital) decisions.

Additionally, for those who choose against further education and development of human capital, an increase in nutrition during childhood will still have a positive effect on future productivity by way of ***increased vitality and cognitive ability***. Studies have shown that improved nutrition strengthens a person's cognitive processes allowing for faster reaction times and better performance on psychoanalytical tests (Pollitt, Gorman, Engle, Rivera, and Martorell 1995). The consequence of the *increased vitality and cognitive ability* criteria is that a person or

[9] For more on this, visit the CDC: http://www.cdc.gov/nccdphp/publications/aag/dnpa.htm, or WHO: http://www.who.int/nutrition/en/

[10] See Alpert and Fava for the influence of folates on Depression: <http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=9212690&dopt=Abstract>

[11] In 2000, 11% of Italy's labor force and 25% of Denmark's labor force had completed tertiary education (World Development Indicators)

population with a strong nutritional background that chooses not to develop their educational potential will still be more productive then a control group with poorer nutrition.

The above argument may appear as path dependency. A criticism of the theory presented here could argue that familial heritage determines the likelihood with which students will be successful in school. However, this argument is hard to discern from the possibility that people who receive a higher education are likely to provide better nutrition to their children which in turn improves their cognitive functions, increasing their demand for education. Since these results are observationally equivalent, it may be difficult to determine the results even using causality tests. In Model 2 presented below, we test this theory with our best available evidence; however, due to empirical limitations, the study of causality may be more conclusively conducted through several different panel surveys.

Hypothesis 2: Net Nutrition effects labor productivity through:

1. Development of Human Capital

2. Increased Vitality and Cognitive Ability

In summary, I argue that net nutrition during the first twenty years of life determines the level of human capital development as well as a person's vitality and cognitive ability, which comprise the most important factors in improving a person's productivity in the labor force. This argument should not be confused with nutrition only influencing human capital, because human capital decisions are choice variables, and hence a person may choose to not further their education but will still experience a relative increase in productivity over that of a person with poorer nutrition. Consequently, an increase in net nutrition, as represented by height, can be expected on average to yield a more productive individual.

2. Contributing factors to labor productivity

(Factors Exogenous of Heights)

The economic histories presented above generate a series of challenges to the empirical testing of net nutrition's impact on labor productivity. For example, the choice to index industrial wages to inflation in Italy between 1975 and 1984 led to an increase in the wage rate of the population. Consequently, when this policy was abandoned with a new political regime in the mid-1980s, there was a distinctive stagnation for the next 10 years. Furthermore, the rise of the welfare state has caused a marked change in incentives that, arguably, have encouraged more laborers to pursue leisure time.[12] These policy decisions may have positive or negative influences on the overall wage rate. Hence, it is necessary to account for these adjustments in the calculations that follow.

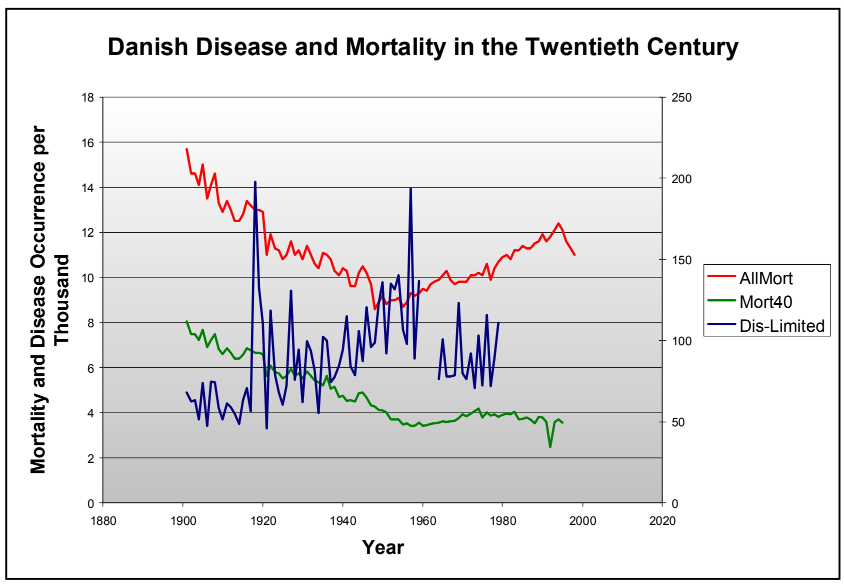
Previously, we noted that disease had an influence on a person's ability to develop human capital and may have a direct influence on height change over time. Here, we hypothesize that disease may have a direct influence on labor productivity because a person who is sick, either chronically or by infectious disease, could be hindered in his or her ability to contribute productively to the labor force. Using reported infectious disease occurrences in Denmark from 1901-1980, we are able to establish a measure of infectious disease occurrence per thousand.[13] Unfortunately, the data is not distributed by age group so we are unable to ascertain the effect of these infectious diseases on age cohorts of varying nutrition levels (we would, of course, expect that an increase in nutrition would reduce disease occurrence). However, we are able to use this data to better understand the effects of infectious disease over time.

[12] This argument is reinforced by the decline in average hours worked by laborer. See Wright (2004) for a discussion on the strengths of GDP/HW as a measure of productivity (3-418).

[13] Diseases included are: Typhoid Fever, Epidemic Cerebrospinal Meningitis, Scarlet Fever, Whooping-Cough, Diphtheria, Influenza, Measles, German Measles, Mumps, Erysipelas, Rheumatic Fever, Bronchopheumonia, Tracheo-Bronchitis

Our data suggests that infectious disease rates began rising in the first half of the twentieth century before dropping in the 1950s in response to the creation of vaccines to treat many infectious diseases.[14] Disease occurrence tends to vary substantially on a year to year basis as seen in Figure 8. The expected effect of an increase in disease is a decrease in productivity (negative coefficient). It is also plausible that the yearly effects of the disease rate are implicit in the established wage rate, and that the only predictable effects of disease are the results of epidemics which act as shocks to labor productivity. The case of epidemics is tested as a dummy variable, where in the instance of a year surpassing 150 disease occurrences per thousand is considered an epidemical year and is given a value of one, otherwise it takes a value of zero.[15] To avoid multicollinearity, the dummy variable test is run separately from the disease variable test so that the same effect is not included twice.

Figure 8



Source: Denmark Statistik (various years)

Furthermore, Models 1 and 2 account for the influence of capital accumulation effects. The fixed capital stock would be expected to provide a positive influence to labor productivity by adding value to the outputs produced by labor. Hence, we would expect a positive coefficient. For example, following the invention of the assembly line, producers were able to use their employees more

[14] For example, the vaccine for whooping cough was introduced in the 1940s and the instances of whooping cough declined from a high of 80,000 in 1952 to only 1,304 in 1982.
[15] This rate is chosen because expanding the definition to include years with disease rate above 100/1000 gives 21 instances instead of 2 for 150/1000. Furthermore the 2 values that are above 150/1000 border on 200/1000 and are well known years for influenza epidemics.

efficiently and garner greater output per employee. This increase in productivity theoretically has an effect on the overall labor productivity. We would expect an increase in labor wages because new machinery requires a certain level of expertise in order to operate, therefore owners would choose to pay higher wages versus retraining a new laborer to work at a lower wage. Therefore the expectation is a positive coefficient for capital accumulation.

Another expectation is that migratory outflows (or inflows respectively) will affect the wage rate in the next year. Migration can result in large additions or subtractions from the labor force, and therefore may result in an overall shift in labor productivity. However, it is difficult to understand exactly how this variable should act. The explanation offered by Williamson in his discussion on the effects of globalization states that 70 percent of wage convergence from 1870-1910 is explained by mass migration (Williamson 295). Anecdotally, we would expect that the emigration of 5.6 million Italian people from 1951-70 would have a substantial effect on labor productivity. The fact that 62.3% of the emigrants were from the poor southern regions of Italy suggests they were leaving their homes in search of higher wages. Since these emigrants would have been poor performers in their former economy, the expected effect of net out-migration is an increase in labor productivity (positive coefficient). Similarly, a net in-migration should result in a reduction in the overall labor productivity, because the incoming populations are coming from a less productive background. These results are predicated on the assumption that the people leaving a country are the less productive of a population and desire to go to a location where there is a high labor demand in order to increase their wealth.

In testing migration, we use net in-migration lagged by one year, because people who choose to migrate in year x may still participate in the labor force in year x. Hence, a shift in productivity may not arise until year $x+1$. If data was available for monthly migration levels, we could weight the data for a more accurate understanding, but, due to time constraints, we use only the yearly net in-migration rates lagged one year. As a result, the usage of lagged migration preempts an argument that migration is a consequence of labor productivity in a given year, though it remains plausible that migration is a consequence of path dependence in labor productivity. A possible test for path dependence would be to evaluate the wage rates in the countries which people are immigrating to, and use this as a proxy of the wage convergence that Williamson suggests. If Williamson is correct, then we could expect that wage convergence would result in reduced migration. If wage convergence did not result in reduced migration, then path dependency in labor productivity could be a plausible theory. However, due to time and space constraints this test is omitted.

Policy choices have the possibility of affecting overall wage rates. As in the Italian case, the indexation of industrial wages spurred further inflation because the indexation was implemented periodically and after inflation had occurred. The consequence of this policy would be further inflation and destabilization of the economy (as discussed in greater detail under data and source). In addition, both Italy and Denmark have high levels of social expenditures which have grown throughout the time period we analyze here, it is plausible that they may have played a role in depressing labor productivity more recently by changing labor incentives. Empirical data shows that annual hours worked per person have declined for Italy from 2,714 hours per year in 1890 to 1,528 in 1987, and have declined for Denmark from 2,770 in 1890 to 1,669 in 1987 (Maddison 1991, 270). However, the lack of good historical measures of social expenditure prevents the usage of this variable in the first model. The model does include a dummy variable for the Italian wage indexation instance which takes on a value of one for years 1975-1984 and a value of zero all other times. A lack of good data on social expenditures over this period precludes a test controlling for increased social expenditures and taxation. No other major policy decisions in either Denmark or Italy upon brief review of these countries' economic histories seem to suggest a policy that would affect the wage.

The lack of height data for women requires the assumption that female height distribution varies at the same pace as men's height. From available data, we understand that the inclusion of women in the work force would cause the average height distribution of the labor force to decline. Both Italy and Denmark have experienced a larger portion of their labor forces being female, but Italy has lagged behind other European nations in this respect.[16] The further introduction of women into the labor force could be expected to cause a decline in the overall wage rate. It is plausible that longitudinal studies could be used to extrapolate the height distribution of women back to the beginning of the 20th century. However, the more significant challenge comes in finding meaningful estimates of the age distribution of women in the labor force dating back that far. Since the empirical hurdles to include this information would likely make the data suspect, we believe that the information of male height distribution should suffice for a strong empirical test of the hypothesis 1.

IV. *Data and Sources*

The data used in this study comes from annual country abstracts of Denmark and Italy, as well as various collections of international historical statistics, and the recently released data from the European Union's KLEMS project.[17] Where there was missing data, I interpolated the

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[16] Females as a percentage of the labor force – Denmark: 1950=33.7%, 1987=45.9%; Italy: 1950=25.5%, 1987=36.1% (Maddison 1991, 245)

[17] EU KLEMS is a statistical and analytical research project financed by the European Commission through the 6th R&D Framework Programme. The EU KLEMS growth accounts also include input measures of various categories of capital (K), labour (L), energy (E), material (M) and service inputs (S). Productivity measures are developed, in particular with growth accounting techniques.

necessary information where appropriate.[18] The calculation of the age-distributed heights of the labor force (described in the next section) requires an additional 50 years of data prior to the year it represents. Height data from Italy is available back to 1874; however, the oldest age distribution of the labor force is given in 1936 (which is the year the Italian data set began). For Denmark, yearly height reports begin in 1911, but other measures exist as far back as 1852. To interpolate this information, I use 5 year height changes in Sweden which, arguably, shares a similar history with Denmark.[19]

The measure used for labor productivity in the first model is the average wage for industrial and agricultural workers weighted for the composition of each in the labor force (denoted ω). As a result, the influence of transportation and communication sectors (among others) is not included. However, for the years in which this information was available, the empirical tests of this data indicate that the average real wage, weighted for agriculture and industry, captures the majority of wage fluctuation and growth over this time period. Therefore, I believe that the average real wage constructed for the purpose of this paper is a useful and instructive measure of real wage rate.

In the second model, we construct a measure of Gross Domestic Product per hour worked (GDP/HW in text, ϖ in equations) as a measure of labor productivity. This measure is a more aggregated measure of the productivity of the population but assumes that the contribution of those people not in the labor force is zero. GDP/HW is considered by many to be a better estimation of labor productivity because it captures the influence of changes in actual hours worked in the economy and is not as susceptible to many of the endogenous complications as

[18] If a data set had persistent variation, the missing years were excluded from the final analysis.

[19] Using Swedish height data is the best available option even though Sweden's relative wealth exceeded Denmark's for most of the time period 1852-1911. Since both economies were primarily agriculturally based up until the mid-1920s, and share common geographical similarities, it is my proposition that they exhibit similar nutrition history fluctuations throughout this time period.

wages.[20] Furthermore, the total hours worked in most modern economies have declined over the 20th century, which indicates that, as people have become more productive, they have chosen to substitute greater income for greater leisure time. Ideally, both models would use GDP/HW; however, a good methodology has yet to be created to extrapolate this information back in time.

An important consideration in this study is the influence of modern wage indexation policies in both countries. Since wage indexation became a popular policy in the 1970s, the real wage over this time period has risen to a level which has maintained its relative value over time. Studies on the indexing of wages have generally shown that, ex ante, and in the early stages of inflation, wage indexation may reduce the extent of a recession; however indexation in the late stages, or ex post, may exacerbate inflation (Fischer 1988, 45). Furthermore, recent studies have shown that the majority of wage indexation policies are implemented periodically and based on lagged inflation causing the majority of policies to destabilize output and further inflationary pressures, regardless of shocks being real or nominal (Jadresic 2002, 194). In applying these concepts to the model used here, we can expect that wage indexation policies are likely to disrupt real wage calculations because recorded wage levels will fail to accurately reflect wage indexation's indeterminate effect on further inflation.

Mortality rate is a commonly used proxy for disease, and is measured as the aggregate number of deaths per thousand people in an economy (μ). A more accurate measure of disease's influence and persistence over this period could be exhibited in the disease rate; however, this information, as well as male and age distributed measures of the mortality rate do not exist over the entire time period. The challenge in using the mortality rate of the overall population is that if a population becomes older overall, the mortality rate will naturally increase (similarly, as it

[20] Recalling Keynes' classical argument that wages are sticky downwards, it is easy to see that the measure of GDP/HW is unaffected by these proposed influences because it measures the aggregate productivity of the labor force, instead of the average portion of revenue paid to those who work in the labor force.

becomes younger, it will naturally decrease). For the purposes of our model, we have extended the age distributed mortality rates back based on the changes in the overall mortality rate.[21] As a result, we will use the mortality rate for males ages 40-44 for Italy, and for ages 40-49 for Denmark as a proxy for the disease rate in each country.[22]

Capital Accumulation (κ) is measured by the levels of fixed capital in a country in a given year. In Model 1, this data comes from B.R. Mitchell's *International Historical Statistics*, and is controlled for in constant prices. For Model 2, we utilize the fixed capital accumulation as calculated by the World Development Indicators Database in year 2000 U.S. dollars. Additionally, migration (γ) is represented by net out-migration (emigration-immigration) and lagged one year due to the reasons described in Section III. Finally the shocks include years 1915-1918, 1939-1945 for War Shocks (other wars were negligible during this time frame); 1918, 1957 for Disease shocks; and 1975-1984 for Policy Shocks, representative of Italy's experimentation with state sanctioned industrial wage indexation.

V. *Labor Productivity Models*

Model 1: Wage Model & Results

Using the variables above, I construct a model that can be tested empirically in order to gather a better understanding of what influences height. The model is represented by a series of

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[21] This extrapolation rests upon the assumption that the mortality rate changes exhibited prior to 1972 were less due to changes in the age composition of the population, but due to disease. A better designed extrapolation would include the changes in the age composition of the labor force as a portion of the calculation, which is not done due to time limitations.

[22] A Prais-Winston adjustment controlling for serial correlation between disease occurrence, height (exogenous variables), and mortality for ages 40-49 (endogenous variable) shows that mortality at age 40 is determined by net nutrition and disease occurrence in a given year. However, by using mortality in our equations, we are introducing another degree of autocorrelation, thereby reinforcing the need for tests controlling for 2nd and 3rd degree autocorrelation.

lagged variables (height and migration), yearly variables (mortality as a proxy for disease, and capital accumulation), and dummy variables (policy shocks, disease shocks, and war shocks).

The labor productivity (ω_m) in year m represents the real wage rate as calculated by the nominal wage index divided by the consumer price index in the same base year. The average height of the labor force is given by equation 1.

$$\lambda_m = \left(\sum ((Height)_n \bullet (Percentage\ Population\ of\ \ Age\ n\ in\ Labor\ Force)_n)\right) \qquad (1)$$

The dependent variable is labor productivity as represented by the real wage rate, and is regressed on a constant α; the exogenous variables (coefficient β): average height of the labor force (λ), mortality of males age 40-49 (μ), capital accumulation (κ), net out-migration (γ); and the dummy variables (coefficient δ) for policy shocks, disease shocks, and war shocks. Thus the model is given by equation 2.

$$\omega_m = \alpha + \beta_1\lambda_m + \beta_2\mu_m + \beta_3\kappa_m + \beta_4\gamma_{m-1} + \delta_1(Policy\ Shock)_m + \delta_2(Disease\ Shock)_m + \delta_3(War\ Shock)_m \qquad (2)$$

The expectation is that height (as a measure of net nutrition), capital, migration, and policy shocks will all have positive signs while net out-migration, disease shocks, and war shocks should all have negative signs. Additionally, from the construction of the equation, it should be clear that a regression such as this has a high probability of serial correlation, which will be confronted in Model 2. This model, however, is important for conceptualizing and understanding which factors may have the most significant effects on nutrition and, most importantly, ensuring that each factor is acting in the direction we would expect.

The results are presented in Table 1, and show that most of the exogenous variables exhibit significance based upon the country in question, with the exception of height which is significant in both countries. The results show strong support for our hypothesis that net nutrition has a significant impact on labor productivity. Taken alone, height has a very high correlation with labor productivity in both instances. Additionally, most of the variables exhibit coefficient signs that are in the correct direction. The two which do not are mortality and disease shock. Disease Shock is not significant in either year, so it is likely that the variable is either too specific (it is limited to two years), or that it is simply not important in this model. More interestingly however, is that mortality at the age of 40 indicates that death increases as productivity increases. This sign change is indicative either of a serial correlation problem or that it may be serving as a proxy for something other than disease.[23] This is an important note because the usage of mortality rate as an instrument for disease is common in the literature and the usage of it as a measure of morbidity, at least in the case of infectious disease, is suspect. When replacing the mortality variable in Denmark with the estimate of disease occurrence from Danish Statistical Abstracts, we get the expected sign (See Table 2).

The fact that only height remained highly correlated throughout this model alludes to the importance of it as a factor in labor productivity changes. As argued earlier in this paper, the relationship between height and labor productivity is through human capital development and increased vitality and cognitive abilities. Therefore, we see that the rise in nutrition clearly relates to labor productivity. In determining causality, it is important to recall that the average height of the labor force is complete and unchanging in any given year because the final adult height of the labor force is achieved across the 50 years prior (with the minor exception of men 15-19 years of age). Therefore, the age-distributed height of the labor force acts like a lagged variable and can not be interpreted as having causality in the opposite direction. In a more concrete sense, consider the actual effects of what is occurring in the regression. If causality runs from height to labor productivity as I posit, then the hypothesis of nutrition influencing

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[23] As discussed earlier, with the rise in the size of the elderly population as a percent of the population overall, it is understandable why the mortality level of the population might increase as described earlier.

productivity is a credible proposition. However, the reverse of labor productivity influencing the age-distributed height of the labor force is theoretically impossible. This is because the wage of a person in year 2000 could not influence the height of someone who is being conscripted in 1960 (who in turn is contributing to the year 2000 labor force at the age of 60). Therefore, the reverse consideration is implausible. The only way that a causal relationship could occur from labor productivity to the age-distributed height of the labor force is if the wages of someone in the current term contribute to 15-19 year olds in the labor force in the same year or in the four years prior. However, 15-19 year olds make up such a small portion of the labor force that I believe this effect is negligible and the results are more apt to reinforce my hypothesis.

Model 2: Serial Correlation Adjustments and Causality

While Model 1 demonstrates clearly that there is a relationship between height and labor productivity, Model 2 clarifies this relationship by removing serial correlation and analyzing the role of human capital as a critical and common intermediate between nutrition and labor productivity. Model 2 varies from Model 1 in that it uses GDP per worker hour in place of wages as a more accurate measure of productivity. Using GDP per Work Hour, we may again run the same regression, only this time:

$$\varpi_m = \alpha + \beta_1\lambda_m + \beta_2\mu_m + \beta_3\kappa_m + \beta_4\gamma_{m-1} + \delta_1(\mathit{Policy\ Shock})_m + \delta_2(\mathit{Disease\ Shock})_m + \delta_3(\mathit{War\ Shock})_m \quad (3)$$

Again, the DW statistic is still indicative of a serially correlated relationship (I omit the table because it is not substantively different from Table 1). Because of the limited data availability for GDP/HW, the relationship is restricted to only 1970 onward. Instead of studying all the aspects discussed previously, we now consider only the impact of height on labor productivity and the impact of secondary educational achievement within the economy on labor productivity.

Therefore I conduct a Cochrane-Orcutt AR(1) regression (CORC) which uses OLS to generate residuals that are then used to perform a new regression based on the assumption that the correlation coefficient (ρ) is associated with the errors of adjacent time periods. The residuals are then used to estimate a new ρ that is then transformed via a generalized differencing transformation process. This generates new coefficients, which are substituted back into the original equation. The process is repeated until the new estimates of ρ differ by less than .01, or it conducts more than 100 iterations (Pindyck and Rubenfeld 140).[24] The result of this test is a new set of coefficients which adjust for serial correlation.

In applying CORC to equation (2) in Model 1, convergence was either not achieved, or the DW-stat remained significant to the point that the null hypothesis - $\rho > 0$ - could not be rejected. However, using the information collected as part of EU KLEMS, we are able to run these tests and discover nutrition's impact on GDP/HW, a better measure of labor productivity. The result of this test is presented in Table 3. I find that the relationship between height and GDP/HW is still significant at the 1% level. Additionally, the DW-Stat can now be accepted ($\rho = 0$). Thus we have established that, even controlling for serial correlation, there is a strong relationship between net nutrition and GDP/HW. Furthermore, based on the same logic in the discussion on Model 1, we may infer that the relationship runs in the causal direction of net nutrition to labor productivity.

When I run a similar model based on the Labor Force's Achievement of Secondary Education (ψ) I find similar results, as shown in Table 4.[25] However, the differences here lead

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[24] These tests were conducted in STATA using the CORC command. See Cochrane and Orcutt 1949 for further details.

[25] Secondary Achievement is calculated by the number of student enrolled in secondary education divided by the population ages 15-19 and then distributed across the age distribution of the labor force. This method is similar to that used to calculate the age-distributed height of the labor force. It should be noted that ψ exhibits the same problems as λ in that they are both likely to understate the actual value of the given variable in the labor force because higher educated people are more likely to be economically active.

us to an intriguing question. Specifically, we note that the explanatory value of height is less in the more developed economy of Denmark. Similarly, educational achievement is more predictive in the developed economy. This suggests that countries may exhibit decreasing returns to nutrition and that, as nutrition's effects on productivity declines, they are then picked up to a greater extent by education. Hence this reinforce an argument made in the beginning, that the influence of nutrition diminishes as the length of time people are developing their human capital increases (more kids are going to college and graduate schools). This theory is testable with additional country studies similar to those offered here.

Finally, I use a Granger Causality test to ascertain the direction of causality. The Granger Causality test examines if $\psi \rightarrow \lambda$ and if $\lambda \rightarrow \psi$. I test the null hypothesis that ψ *does not cause* λ, by running the following regressions:

$$\begin{cases} \psi = \sum_{i=1}^{m} \alpha_i \psi_{t-i} + \sum_{i=1}^{m} \beta_i \lambda_{t-i} + \varepsilon_t & (4) \\ \\ \psi = \sum_{i=1}^{m} \alpha_i \psi_{t-i} + \varepsilon_t & (5) \end{cases}$$

and use the sum of squared residuals from (4) and (5) to calculate an F-statistic (Pindyck and Rubenfeld 216).[26] The test must be applied in both directions in case causality is shown both ways (bidirectional causality), which is what occurs in the instance presented here. The test, as shown in Table 5, is indeterminate, and it is likely that with high serial correlation the respective number of lags used in this test were not enough to decipher a clear and convincing argument one way or the other. A larger data series might aid in clarifying the results (the data series used here do not exceed 30 years for lack of information on GDP/HW), but it is also equally likely

[26] The Granger test may be run in STATA after run a Vector Autoregression and specifying a certain number of lags. In order to estimate the optimal number of lags, I use the same number of lags that optimizes the calculation of Akaike's Information Criterion (AIC). For further information on the Granger Causality test consult Granger 1969.

that, similar to in Model 5, we could hypothesize that the effects of both education and nutrition matter more in differing stages of development.

The models and results presented as part of Model 2 have demonstrated in a clear manner that, even controlling for serial correlation, net nutrition has a significant and positive effect on labor productivity. Additionally, we see that, similar to our conjecture at the beginning of this article, our current methodology and data availability prevents us from rigorously testing our theory as it pertains to nutrition's impact on education, and vice versa. For this, I believe we can benefit from the growing number of micro-level studies in developing countries that explore this relationship (see Behrman, et. al. 2006, Case and Paxson 2007, and Pollitt, et. al. 1995). The direction of this literature thus far reinforces the causation in favor of the theory presented here.

VI. *Conclusion*

I theorized that net nutrition has a significant impact on labor productivity and the aforementioned analysis provides convincing evidence. Empirically, I used wage as a proxy for labor productivity to show that nutrition over the twentieth century had a substantial and leading role in productivity growth. Moreover, data from 1970 to 2000 shows that GDP per worker hour (a better measure of labor productivity) is significantly influenced by net nutrition even after controlling for serial correlation. Additionally, I found that such factors as capital accumulation, disease occurrence, migrations, policy shocks, epidemical shocks, and war shocks, may or may not have an effect, depending on the country, but continue to be hard to decipher due to high-order serial correlation problems.

The empirics presented in Model 2 reinforce hypothesis 2, which states that nutrition furthers human capital accumulation as well as strengthens vitality and cognitive ability, which, in turn, increases productivity. However, the result is not conclusive and requires further iterations and longer data series to provide more convincing results. The challenge that remains for future empirical research is to develop a clearer understanding of how and when net nutrition influences, or is affected by, the educational achievement of a country's labor force.

Further research into this area should extend data series farther back in history in order to garner a better understanding of how changes over time have affected labor productivity changes. Furthermore expanding the analysis beyond simply these two countries would be of great help in understanding how and under which circumstances the effects of nutrition or educational achievement become more significant. We have posited a plausible theory here as to the possibility of diminishing nutritional returns to wealth increases.

Additionally, beyond data expansion and further testing, it is very important to gain a more accurate understanding of how the entry of women into the labor force has altered productivity. Micro-level studies appear to be the most likely to reinforce theory because they offer a wealth of information and specifics that are substantially less accurate on the macro-level (for example, while our height data is very reflective of the population, we are unable to determine the effects of lineage or short-term dietary changes on future productivity, whereas panel data generally offers more of this information). The advantage to the analysis conducted here is that it concerns changes at the country level, which offers the results of aggregated and collective choices.

A clearer understanding of nutrition's role in furthering labor productivity permits a better understanding of the underlying human factors in economic growth. To understand how a person (as well as a society) may become more or less productive as a result of varied inputs allows for a more strategic approach in applicable policy and development decisions.

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Table 1

Denmark Regression Analysis

	Labor Productivity (Real Wage)	Coef.	Std. Err.	t-stat	P>t		
OLS	Height	0.1065	0.0026	40.59	0.00	R^2	0.957
	Constant	-17.83	0.45	-39.53	0.00	Adj. R^2	0.9564
						DW-Stat	0.12038

	Labor Productivity (Real Wage)	Coef.	Std. Err.	t-stat	P>t		
OLS	***Height	0.1035	0.0069	14.99	0.00	R^2	0.973
	***Mortality of ages 40-49	0.0481	0.0141	3.42	0.00	Adj. R^2	0.9701
	**Capital Accumulation	0.0000	0.0000	2.37	0.02	DW-Stat	0.284
	Lagged Migration (1 year)	0.0008	0.0015	0.55	0.59		
	Disease Shock	0.0042	0.0568	0.07	0.94		
	**War Shock	-0.0547	0.0249	-2.19	0.03		
	***Constant	-17.60	1.17	-15.04	0.00		

Italy Regression Analysis

	Labor Productivity (Real Wage)	Coef.	Std. Err.	t-stat	P>t		
OLS	Height	0.1349	0.0061	22.03	0.00	R^2	0.8949
	Constant	-22.02	1.03	-21.39	0.00	Adj. R^2	0.893
						DW-Stat	0.04448

	Labor Productivity (Real Wage)	Coef.	Std. Err.	t-stat	P>t		
OLS	***Height	0.1410	0.0145	9.75	0.00	R^2	0.9841
	Mortality of ages 40-44	0.0032	0.0329	0.10	0.92	Adj. R^2	0.9814
	Capital	0.0000	0.0001	0.45	0.65	DW-Stat	0.66747
	*Lagged Migration	0.0003	0.0002	1.78	0.08		
	***Policy Shock	0.1421	0.0167	8.52	0.00		
	Disease Shock	0.0088	0.0419	0.21	0.84		
	War Shock	-0.0139	0.0311	-0.45	0.66		
	***Constant	-23.03	2.52	-9.14	0.00		

Notes:

† DW-Stat is not significant at 5% level (reject the assumption that $\rho>0$)
* t-stat significant at 10% level
** t-stat significant at 5% level
*** t-stat significant at 1% level

Both of the DW statistics are significant at the 5% level, meaning that the the assumption ($\rho>0$) is accepted. Hence these OLS regressions' variables are serially correlated, and further tests will be needed to clarify the significance of individual variables. Using Prais-Winsten (AR(1) regression) iterated estimates, and Cochrane-Orcutt (AR(1) regression) iterated estimates we find that height and the shocks that are significant in the OLS test are still significant at the 5% level (the rest are not). However, serial correlation persists, meaning that second-degree serial autocorrelation (or higher) may exist. These relationships are explored later on.

Table 2

Denmark Regression Analysis (II)

	Labor Productivity (Real Wage)	Coef.	Std. Err.	t-stat	P>t		
	***Height	0.1406	0.0168	8.35	0.00	R^2	0.9666
	Disease Occurrence (per 1000)	-0.0006	0.0004	-1.40	0.17	Adj. R^2	0.9616
OLS	Capital Accumulation	0.0000	0.0000	-1.10	0.28	DW-Stat	0.40424
	Lagged Migration (1 year)	0.0018	0.0017	1.05	0.30		
	Disease Shock	-0.0055	0.0643	-0.08	0.93		
	**War Shock	-0.0702	0.0254	-2.77	0.01		
	***Constant	-23.57	2.83	-8.33	0.00		

Notes:

† DW-Stat is not significant at 5% level (reject the assumption that $\rho>0$)
* t-stat significant at 10% level
** t-stat significant at 5% level
*** t-stat significant at 1% level

Cochrane-Orcutt AR(1) regression -- Iterated estimates

Height Only

Denmark

GDP per Worker Hour	Coef.	Std. Err.	t	P>t
***Height	3.166643	0.939524	3.37	0.002
***Constant	-526.703	167.4653	-3.15	0.004
DW-Stat (original)	0.086949		R^2	0.3041
† DW-Stat (transformed)	1.557884		Adj. R^2	0.2773

Italy

GDP per Worker Hour	Coef.	Std. Err.	t	P>t
***Height	4.633239	0.208237	22.25	0.000
***Constant	-748.8733	35.40937	-21.15	0.000
DW-Stat (original)	0.736674		R^2	0.9465
† DW-Stat (transformed)	1.90013		Adj. R^2	0.9446

Height and Capital Accumulation

Denmark

GDP per Worker Hour	Coef.	Std. Err.	t	P>t
***Height	2.850994	0.767989	3.71	0.001
Capital Accumulation	7.92E-11	5.99E-11	1.32	0.198
***Constant	-472.5494	136.1119	-3.47	0.002
DW-Stat (original)	0.341883		R^2	0.4689
† DW-Stat (transformed)	1.617084		Adj. R^2	0.4264

Italy

GDP per Worker Hour	Coef.	Std. Err.	t	P>t
***Height	3.984788	0.399915	9.96	0.00
*Capital Accumulation	2.75E-11	1.55E-11	1.77	0.09
***Constant	-643.3241	65.97662	-9.75	0.00
DW-Stat (original)	0.691224		R^2	0.9217
† DW-Stat (transformed)	1.819618		Adj. R^2	0.9159

Notes:
Addition of further variables generally destabilized the estimates. This issue is likely due to higher order serial correlation between the variables. This problem could be corrected using higher order autoregressive tests, but would require a larger sample size.

† DW-Stat is not significant at 5% level (reject the assumption that ρ>0)
* t-stat significant at 10% level
** t-stat significant at 5% level
*** t-stat significant at 1% level

Cochrane-Orcutt AR(1) regression -- Iterated estimates

Educational Achievement Only

Denmark

GDP per Worker Hour	Coef.	Std. Err.	t	P>t
***Educational Achievement	55.25959	5.689361	9.71	0.000
***Constant	8.819923	2.636597	3.35	0.003
DW-Stat (original)	0.077487		R^2	0.7839
† DW-Stat (transformed)	1.554294		Adj. R^2	0.7756

Italy

GDP per Worker Hour	Coef.	Std. Err.	t	P>t
***Educational Achievement	0.3370806	0.019351	17.42	0.000
***Constant	17.35917	1.35211	12.84	0.000
DW-Stat (original)	0.559468		R^2	0.9073
† DW-Stat (transformed)	1.61837		Adj. R^2	0.9043

Educational Achievement and Capital Accumulation

Denmark

GDP per Worker Hour	Coef.	Std. Err.	t	P>t
***Educational Achievement	51.61862	6.703284	7.7	0.000
Capital Accumulation	6.08E-11	5.90E-11	1.03	0.312
***Constant	9.176828	2.780312	3.3	0.003
DW-Stat (original)	0.357614		R^2	0.7733
† DW-Stat (transformed)	1.597518		Adj. R^2	0.7552

Italy [1]

GDP per Worker Hour	Coef.	Std. Err.	t	P>t
***Height	0.317232	0.036871	8.6	0.00
*Capital Accumulation	2.92E-11	1.59E-11	1.84	0.08
***Constant	12.83684	1.930034	6.65	0.00
DW-Stat (original)	0.575565		R^2	0.8641
DW-Stat (transformed)	1.292437		Adj. R^2	0.8553

Notes:

1. When Capital Accumulation was included for Italy, the CORC Adjustment did not converge. Instead, a Prais-Winston Adjustment is used, which turn out still have serial correlation problems.

† DW-Stat is not significant at 5% level (reject the assumption that ρ>0)
* t-stat significant at 10% level
** t-stat significant at 5% level
*** t-stat significant at 1% level

Table 5

Granger Causality Wald Tests

Denmark

Equation		Excluded	X^2	df	Prob > X^2
Educational Achievement	→	Height	17.078	1	0
Height	→	Educational Achievement	85.498	1	0

Italy

Equation		Excluded	X^2	df	Prob > X^2
Educational Achievement	→	Height	25.269	1	0
Height	→	Educational Achievement	10.636	1	0.001

Appendix

Figure A1

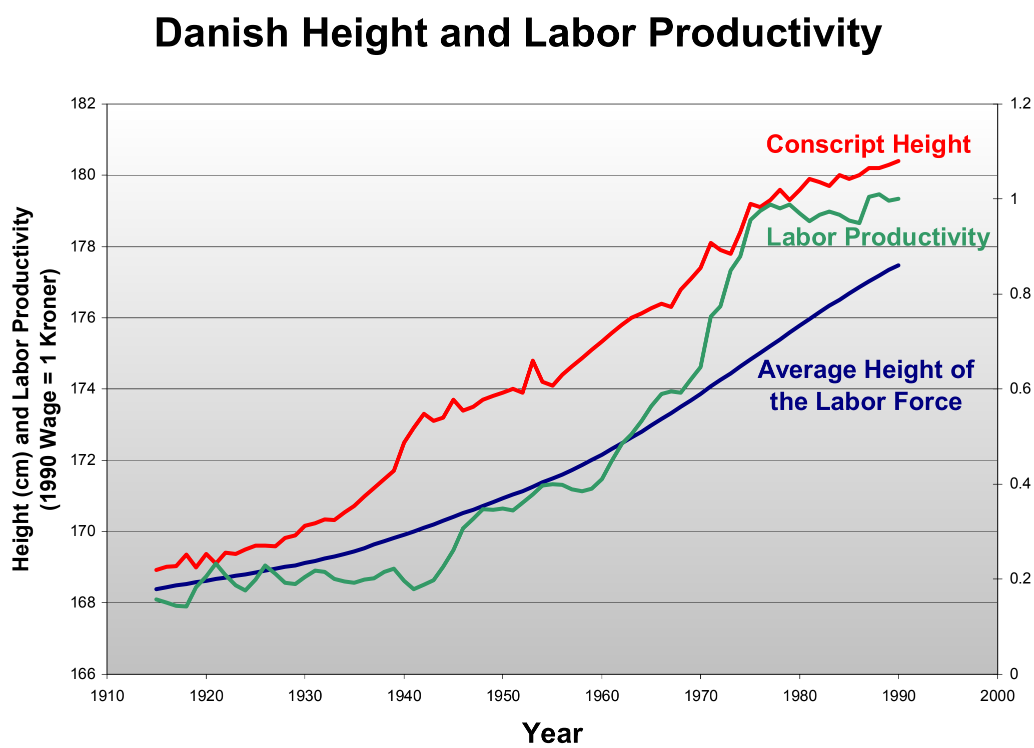

Figure A2

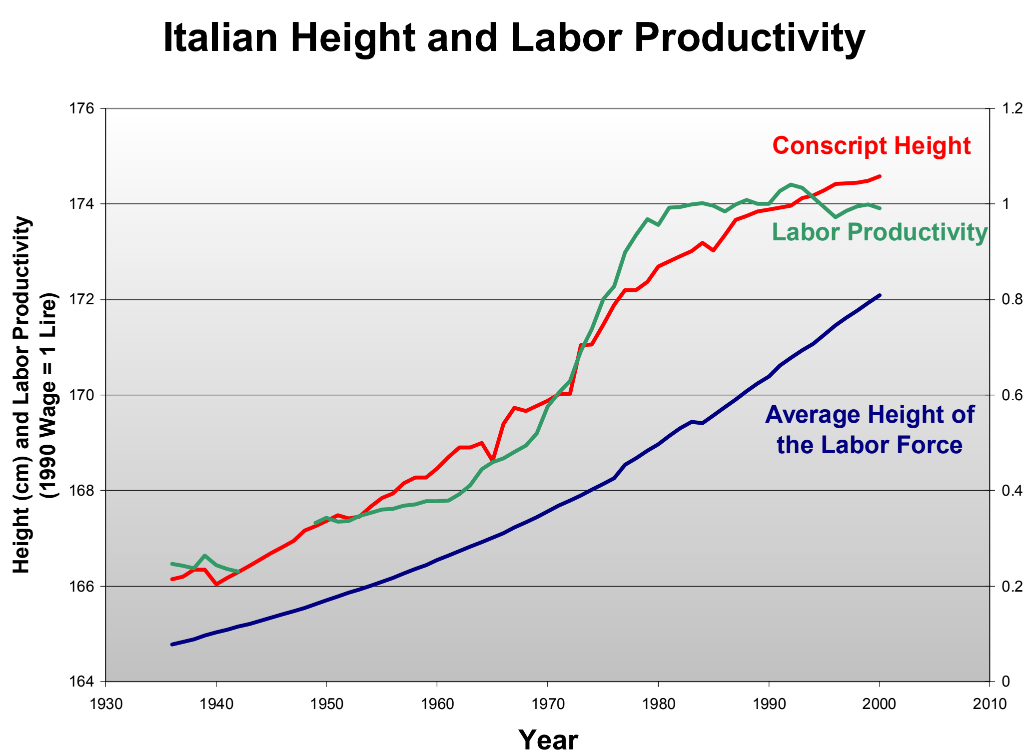

Figure A3

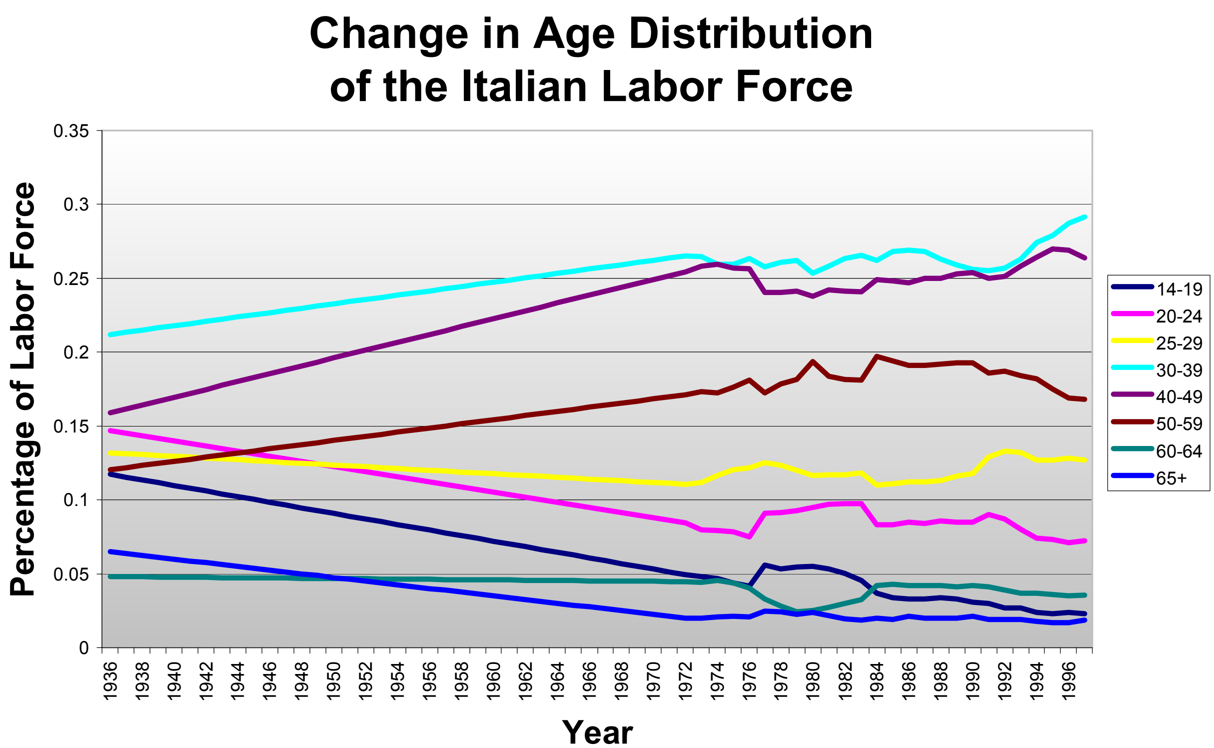

Figure A4